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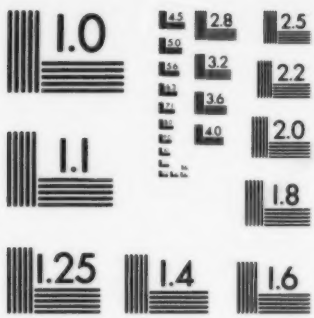

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INVESTIGATION TO PRODUCE AN IRON CONCENTRATE OF LOW MANGANESE CONTENT FROM WABUSH ROUGHER SPIRAL TAILINGS

by

W.H. Cameron* and V.G. Reynolds*

SUMMARY

An investigation into producing an acceptable iron ore concentrate from Wabush Rougher Spiral Tailings was done using reverse iron ore flotation followed by magnetic separation. The target set for the final product was 65% Fe at a minimum recovery of 80% with less than 1.0% Mn and less than 2.0% SiO_2. The spiral tailings as received contained 36.30% Fe, 4.67% Mn and 36.76% SiO_2. The best flotation product contained 57.73% Fe at a recovery of 96.38% Fe, 7.59% Mn and 1.74% SiO_2.

Concentrates from 3 floats were combined into a composite and subjected to Low and High Intensity Wet Magnetic Separation. A final product was produced containing 64.10% Fe at a recovery of 76.7% Fe, 1.23% Mn and 0.69% SiO_2.

These values fell slightly outside the target and while it was felt that the Fe grade and recovery could be improved, most of the Mn left was in solid solution and the only way of reducing it would be by leaching which the Company had already rejected as being too costly.

Keywords: Reverse Flotation, Grade, Recovery, Wet Low Intensity Magnetic Separation, Wet High Intensity Magnetic Separation.

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*Physical Scientists, Ore Dressing Section, Mineral Processing Laboratory, Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada.

ÉTUDE EN VUE DE PRODUIRE UN CONCENTRÉ DE MINERAI DE FER À FAIBLE TENEUR EN MANGANÈSE À PARTIR DES RÉSIDUS DE SPIRALE DE DÉGROSSISSAGE DE WABUSH

par

W.H. Cameron* et V.G. Reynolds*

RÉSUMÉ

On a effectué une étude portant sur la production d'un concentré de minerai de fer à partir des résidus de spirale de dégrossisage de Wabush. Le concentré de minerai de fer a été soumis à la flottation inversée et ensuite, à la séparation magnétique. On visait à obtenir un produit final ayant une teneur en fer de 65 % pour un taux de récupération minimal de 80 %, et contenant moins de 1,0 % de manganèse (Mn) et moins de 2,0 % d'oxyde de silicium (SiO_2). Le meilleur produit obtenu par la flottation avait une teneur en fer de 57,73 % pour un taux de récupération de 96,38 % Fe, 7,59 % Mn et 1,74 % SiO_2.

Les concentrés obtenus à partir de trois essais de flottation ont été combinés pour former un composé et soumis à la séparation magnétique à haute intensité et à faible intensité par voie humide. On a obtenu un produit final ayant une teneur en fer de 64,10 % pour un taux de récupération du fer de 76,7 %, du manganèse, de 1,23 % et d'oxyde de silicium, de 0,69 %.

Ces valeurs n'étaient pas tout à fait conformes à celles que l'on désirait obtenir et bien qu'il aurait été possible d'améliorer la teneur en fer et le taux de récupération du concentré, la plupart du manganèse restant se présentait sous forme de solution solide. La seule façon de le réduire aurait été la lixiviation, solution que la société avait déjà rejetée en raison de son coût.

Mots-clé : Flottation inversée, qualité ou teneur, récupération, séparation magnétique à faible intensité par voie humide, séparation magnétique à haute intensité par voie humide.

*Scientifiques, spécialistes en sciences physiques, Section de la minéralurgie, Laboratoire de traitement des minéraux, Laboratoires des sciences minérales, CANMET, Énergie, Mines et Ressources Canada.

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INTRODUCTION

Upon studying several proposed flowsheets for fine iron recovery at the Wabush Scully Mine it was noticed by the authors that each flowsheet indicated wet screening of rougher spiral tails on a 150 M screen followed by further gravity, electrostatic or magnetic treatment. One other option was flotation, but upon inquiries to the company it became apparent that no one intended to investigate this particular alternative. With this in mind the authors decided to pursue the flotation option being cognizant of the fact that one of the characteristics of Wabush ore is its high manganese content. The target was an iron concentrate assaying a minimum 65% Fe, <1.0% Mn and <2.0% SiO_2 at an Fe recovery of 80% or greater.

Rougher Spiral Tailings Sample

The samples used in the experiments were obtained from 3-45 gal drums of Wabush Mines rougher spiral tailings which had originally been intended for gravity studies on the Reichert trays. These studies were precluded by the work done at CANMET by Laplante and Nudo using Reichert trays for fine iron recovery on Quebec Cartier Mining tails. The Wabush tails had been obtained in early 1985 along with an iron distribution by size fraction done on the Quarterly Composite Analysis - 4th Quarter, 1984 shown in Table 1.

It may be noted from Table 1 that the -150 M fraction comprises only 30.27% of the total weight of tailings but contains 56.62% of the Fe values; hence the wet screening on the flowsheets at 150 M.

Table 1 - Spiral tailing Fe distribution by size fraction

Mesh	% Wt		Fe assay %	Fe distribution %	
+14	1.00		32.23	1.63	
+20	2.17		30.51	3.35	
+28	4.01		23.84	4.83	
+35	6.35		15.77	5.06	
+48	15.05		9.99	7.60	
+65	17.56		8.19	7.27	
+100	13.04		9.11	6.01	
+150	10.53		14.34	7.63	
+200	8.19		24.71	10.23	
+270	5.85		39.78	11.76	
+400	3.68	30.27	40.83	7.60	56.62
+500	2.01		40.83	4.15	
-500	10.54		42.94	22.88	
Calculated head	100.00		19.79	100.0	

The following Table 2 has been recalculated from Table 1 in order to obtain a calculated average head assay of the -150 M spiral tailing.

Table 2 - Calculated average head sample of -150 M spiral tailing

Mesh	% Wt	Fe assay %	Fe distribution %
+200	27.05	24.71	18.06
+270	19.33	39.78	20.78
+400	12.16	40.83	13.42
+500	6.64	40.83	7.33
-500	34.82	42.94	40.41
Calculated head	100.0	36.99	100.00

Sample Preparation

The contents of the 3-45 gal drums were dumped together and allowed to dry over the period of a week with frequent raking. After complete drying had occurred they were blended together and dry screened on a 10 M screen. The +10 M was set aside and the -10 M was then wet screened on an 80 M Sweco screen with the +80 M being removed. The -80 M was then wet screened on a 150 M Sweco screen with the +150 M again being removed. The -150 M fraction was then dried and split into representative samples for flotation.

Mineralogy and Assays

Samples of the -150 M were sent to Mineralogy for ore microscopy and to the Chemical Laboratory for assay of Fe, Mn and SiO_2. Mineralogy indicated that the samples appeared to be well liberated with a definite pyrolusite-psilomelene fraction being present. The average heads were Fe-36.30%, Mn-4.67% and SiO_2-36.76%. It may be noted that the Fe value of 36.30% agrees quite well with the Fe assay of 36.99% from Table 2 which indicates that the tailings are quite representative of the company's Quarterly Composite Analysis - 4th Quarter, 1984.

TEST PROCEDURE AND RESULTS

Reverse Fe Flotation

As is common practice today reverse flotation was employed, i.e., gangue minerals, namely silicates, were floated away from the Fe. No desliming was done as again, referring to Table 2, 40.41% of the Fe values are in the -500 M fraction. The collector chosen is, from the authors' past experience, very effective in the flotation of finely ground, slimy material, but as a result of not desliming, reagent consumption was higher than normal. Reagents and conditions for three flotation tests are given in Table 3 followed by the results in Table 4.

The collector chosen was Aerosurf MG-98A3 (primary amine), Na_2CO_3 was used as a dispersant and to ensure an alkaline pH, and Dextrin WW-82 was used to depress the Fe. Two drops of MIBC were used in Test 3 to thicken froth.

Table 3 - Reagents and conditions for reverse Fe flotation

Test No.	Opera-tion	Time min	% solids	pH	Modifier - g/t		Total collector employed - g/t
					MIBC		
1					Na_2CO_3	WW-82	MG-98A3
				7.2			
	conditioning	5	45	10.4	2270	908	454
	conditioning	0.5	45	10.3			
	Ro float	6	20	10.1			
	scavenger 1	5	20	9.9			
	scavenger 2	4	20	9.6			
	scavenger 3	4	20	9.4			
2 (1)	conditioning	5	45	10.5	2270	908	
	conditioning	0.5	45	10.3			113.5
	Ro float	1.5	20	10.2			
	Ro float	2.5	20				113.5
	Ro float	2.0	20				113.5
	Ro float	2.0	20	9.6			113.5
	scavenger 1	5	20	9.4			
	scavenger 2	4	20	9.4			
	scavenger 3	4	20	9.4			
3 (1)	conditioning	5	45	10.5	2270	908	
	conditioning	0.5	45	10.3			113.5
	Ro float	1.0	20	10.2	.014		
	Ro float	0.5	20				
	Ro float	2.0	20				113.5
	Ro float	0.5	20				
	Ro float	2.0	20		.014		113.5
	Ro float	2.0	20	9.7			113.5
	scavenger 1	5	20	9.9			
	scavenger 2	4	20	9.5			
	scavenger 3	4	20	9.4			

(1) Collector added in increments rather than total amount at beginning of float.

Table 4 - Results of reverse Fe flotation

Test No.	Product	Wt g	Wt %	Analysis % Fe	Mn	SiO_2	Distribution % Fe	Mn	SiO_2
	1) Fe conc	321.3	53.7	58.71	7.30	1.40	86.43	82.37	2.06
	2) Scav-1	27.0	4.5	51.96	10.00	3.00	6.41	9.46	0.37
1	3) Scav-2	10.6	1.8	49.28	9.50	5.10	2.43	3.59	0.25
	4) Scav-3	5.5	0.9	45.06	9.00	8.78	1.11	1.70	0.21
	Tails	233.6	39.1	3.38	0.35	90.80	3.62	2.88	97.11
	1-4 Combined	364.4	60.9	57.73	7.59	1.74	96.38	97.12	2.89
	Heads (calcd)	598.0	100.0	36.48	4.76	36.56	100.00	100.00	100.00
	1) Fe conc	285.8	47.9	59.19	7.00	0.72	78.33	72.59	0.93
	2) Scav-1	44.8	7.5	53.85	9.20	2.32	11.16	14.94	0.47
2	3) Scav-2	15.6	2.6	51.60	9.20	3.66	3.71	5.18	0.26
	4) Scav-3	7.4	1.3	48.51	9.30	5.32	1.74	2.62	0.19
	Tails	242.9	40.7	4.50	0.53	88.98	5.06	4.67	98.15
	1-4 Combined	353.6	59.3	58.95	7.43	1.15	94.94	95.33	1.85
	Heads (calcd)	596.5	100.0	36.19	4.62	36.90	100.00	100.00	100.00
*	1) Fe conc	287.4	48.1	59.19	7.00	0.72	77.86	72.83	0.94
	2) Scav-1	42.3	7.1	53.85	9.20	2.32	11.33	14.13	0.45
3	3) Scav-2	17.0	2.8	51.60	9.20	3.66	3.95	5.57	0.28
	4) Scav-3	8.2	1.4	48.51	9.30	5.32	1.86	2.82	0.20
	Tails	242.1	40.6	4.50	0.53	88.98	5.00	4.65	98.13
	1-4 Combined	354.9	59.4	58.02	7.42	1.16	95.00	95.35	1.87
	Heads (calcd)	597.0	100.0	36.42	4.62	36.81	100.00	100.00	100.00

*The weight % of the products in Tests 2 and 3 are so similar that it is obvious that the MIBC had no effect on Test 3 and the same assays were used in Test 3 as in Test 2.

Discussion of Flotation Results

After studying the results from Table 4 it becomes apparent that although high recoveries of the Fe can be obtained with low silica grades, the Fe grades were also unusually low. At this stage in flotation one would normally try to optimize the float in order to produce a higher grade Fe concentrate.

This was not done in this case for two reasons:

1. Even if the Fe in the concentrate could be enriched to a higher grade, the concentrate would still be of no value containing approximately 7% Mn.
2. The chances of enriching the Fe concentrate appeared rather poor because it was felt that if the concentrate contained approximately 7.11% Mn, the Mn then was probably displacing the Fe and until the Mn content of the Fe concentrate could be reduced, there was little chance of improving the Fe grade.

The primary consideration then was to reduce the Mn grade in the concentrate which would in all likelihood increase the Fe grade.

A reasonably comprehensive study of the literature concerning Fe and Mn flotation was done but failed to produce any selective collectors or depressants for one and not the other. It soon became apparent that regardless of the modifier used, the Fe and Mn would both respond in the same manner.

This meant that some other method would have to be tried and since the authors were aware that Mn leaching could be done successfully, but was too costly a procedure, it was decided to try and lower the Mn content in the Fe concentrate by Wet High Intensity Magnetic Separation (WHIMS).

To perform the tests, the Fe concentrates from Table 4 were combined into a composite and blended together. The results of this blending of Fe concentrates may be seen in Table 5.

Table 5 - Fe composite made from flotation tests 1, 2 and 3

Flotation Test No.	Product	Wt (g)	Wt %	Analysis % Fe	Mn	SiO_2	Distribution % Fe	Mn	SiO_2
1	Fe conc	321.8	35.9	58.71	7.30	1.40	35.7	36.9	52.1
2	Fe conc	285.8	32.0	59.19	7.00	0.72	32.1	31.5	23.9
3	Fe conc	287.4	32.1	59.19	7.00	0.72	32.3	31.6	24.0
Heads (calcd)	Comp.	894.5	100.0	59.00	7.11	0.96	100.0	100.0	100.0

Some of this composite was split out and retained with 625.0 g being used as feed for the following tests. As can be seen, the average assays for the composite based on 894.50 g were 59.00% Fe, 7.11% Mn and 0.96% SiO_2; 269.5 g were retained for further tests if necessary.

Before subjecting the samples to WHIMS, the 625.0 g of composite was subjected to Wet Low Intensity Magnetic Separation (WLIMS) to separate the magnetite from the hematite, thereby avoiding plugging the WHIMS with magnetite.

The results of the WLIMS may be seen in Table 6 based upon the composite flotation sample from Table 5 with a feed of 625.0 g.

Table 6 - Results from Wet Low Intensity Magnetic Separation (WLIMS)

Test No.	Product	Wt (g)	Wt %	Analysis % Fe	Mn	SiO_2	Distribution % Fe	Mn	SiO_2
1	Mags	36.7	5.9	69.38	1.10	0.46	6.9	0.9	2.7
	N-mags	588.3	94.1	58.29	7.32	1.03	93.1	99.1	97.3
	Flo-comp	625.0	100.0	58.94	6.95	1.00	100.0	100.0	100.0

The hematite from the WLIMS (non-megs.) was oven dried, blended and a number of 50 g samples split out for WHIMS tests. These tests were performed on the Sala Wet High Intensity Magnetic Separator with the conditions under which the tests were performed shown in Table 7 and the results shown in Table 8.

Table 7 - Test condition for Wet High Intensity Magnetic Separation (WHIMS)

Test No.	Feed size	Matrix No.	Field strength	Flow rate mm/s
1	-150 M	56(100 M)	3.0(258 mT)	28
2	-150 M	56	3.0	55.5
3	-150 M	56	2.0(176 mT)	55.5
4	-150 M	56	2.0	105.0
5	-150 M	56	2.0	80.0
6	See footnote 1) following Table 8			
7	-325 M	1/0(270 M)	2.0	105.0
8	-325 M	1/0	2.0	125.0

Table 8 - WHIMS results

Test No.	Product	Wt (g)	Wt %	Analysis % Fe	Mn	SiO_2	Distribution % Fe	Mn	SiO_2
1	Mags			No separation discernible					
	N-mags								
Feed (calcd)									
2	Mags			No separation discernible					
	N-mags								
Feed (calcd)									
3	Mags	46.7	93.2	60.23	6.92	0.91	95.2	87.8	73.8
	N-mags	3.4	6.8	41.32	13.13	4.42	4.8	12.2	26.2
Feed (calcd)		50.1	100.0	58.94	7.34	1.15	100.0	100.0	100.0
4	Mags	37.6	74.8	63.83	4.58	0.72	81.1	47.2	48.9
	N-mags	12.7	25.2	44.05	15.22	2.24	18.9	52.8	51.1
Feed (calcd)		50.3	100.0	58.85	7.26	1.10	100.0	100.0	100.0
5	Mags	43.4	88.2	60.19	2.99	1.17	91.3	36.3	71.5
	N-mags	5.8	11.8	42.63	39.19	3.48	8.7	63.7	28.5
Feed (calcd)		49.2	100.0	58.12	7.26	1.44	100.0	100.0	100.0
	Mags	85.0	42.7	62.48	2.45	0.98	45.3	14.2	40.3
6(1)	N-mags	114.0	57.3	56.21	11.05	1.08	54.7	85.8	59.7
Feed (calcd)		199.0	100.0	58.89	7.38	1.04	100.0	100.0	100.0
	Mags	40.5	84.0	60.72	2.84	1.29	88.1	33.0	61.9
7(2)	N-mags	7.7	16.0	42.89	30.25	4.16	11.9	67.0	38.1
Feed (calcd)		48.2	100.0	57.87	7.23	1.75	100.0	100.0	100.0
	Mags	32.8	68.6	63.61	1.24	0.71	75.0	11.6	34.5
8(2)	N-mags	15.0	31.4	46.25	20.65	2.94	25.0	88.4	65.5
Feed (calcd)		47.8	100.0	58.16	7.33	1.41	100.0	100.0	100.0

(1) In an effort to determine where the greatest concentration of Mn was, 4 of the remaining 50.0 g samples were combined and wet screened on 325 M. As can be seen from the Mn distribution 85.8% is contained in the -325 M fraction.

(2) To test the effect of finer grinding and also to check if the Mn was better liberated, the -325 M fraction from Test 6 were dried, combined and additional 50 g samples split out which were used as feed for Tests 7 and 8.

Discussion of Wet High Intensity Magnetic Separation Results

Examining the results from Table 8, it may be seen that Test 4 at a grind of -150 M gave the highest Fe concentrate of 63.83% Fe at recoveries of 81.1%. However, the Mn assayed 4.58% which is far too high and as a result this test was rejected. The next best result was Test 8 which showed an Fe assay of 63.61% at a recovery of 75.0% Fe and a Mn assay of 1.24.

Although the Fe assay and recovery are still short of the target of 65% Fe and 80% respectively, and the Mn assay is above the target of <1% Mn, it is felt that the magnetite fraction after being added to these figures can improve the overall results. Since the magnetite removed constituted only 5.9 wt. % of the final product, it is doubtful that even the inclusion of the magnetite with the hematite will increase Fe grade and recoveries and decrease the Mn to the targets set, or at least to an acceptable product for Wabush to follow the given methodology in this paper.

In order to determine all the results from Table 8 on a final product basis with the magnetite being combined with the mags, i.e., the hematite concentrate, and the tails being left as shown in Table 8, Table 9 was recalculated from Table 8 on a final product basis in order to determine the best possible grades and recoveries that could be expected from a combination of flotation, WLIMS and WHIMS.

Table 9 - Final product results

Test No.	Product	Wt (g)	Wt %	Analysis %* Fe	Mn	SiO_2	Distribution % Fe	Mn	SiO_2
3	Conc.	585.00	93.6	60.80	6.55	0.88	95.6	87.9	74.4
	Tails	40.00	6.4	41.32	13.13	4.42	4.4	12.1	25.6
	Feed (calcd)	625.00	100.0	59.55	6.97	1.11	100.0	100.0	100.0
4	Conc.	476.75	76.3	64.23	4.29	0.70	82.4	47.6	50.1
	Tails	148.25	23.7	44.05	15.22	2.24	17.6	52.4	49.9
	Feed (calcd)	625.00	100.0	59.45	6.88	1.06	100.0	100.0	100.0
5	Conc.	555.58	88.9	60.78	2.87	1.12	91.9	37.0	72.1
	Tails	69.42	11.1	42.63	36.19	3.48	8.1	63.0	27.9
	Feed (calcd)	625.00	100.0	58.77	6.90	1.38	100.0	100.0	100.0
6	Conc.	287.90	46.1	64.77	2.32	0.93	49.6	15.2	42.4
	Tails	337.10	53.9	56.21	11.05	1.08	50.4	84.8	57.6
	Feed (calcd)	625.00	100.0	59.51	7.00	1.00	100.0	100.0	100.0
7	Conc.	530.87	84.9	61.33	2.72	1.23	88.9	33.6	62.4
	Tails	94.13	15.1	42.89	30.25	4.16	11.1	66.4	37.6
	Feed (calcd)	625.00	100.0	58.56	6.85	1.67	100.0	100.0	100.0
8	Conc.	440.30	70.4	64.10	1.23	0.69	76.7	12.4	35.8
	Tails	184.70	29.6	46.25	20.65	2.94	23.3	87.6	64.2
	Feed (calcd)	625.00	100.0	58.83	6.96	1.35	100.0	100.0	100.0

* For final product results the magnetite concentrate from the WLIMS was added to each of the hematite concentrates from the WHIMS. The tails from the WHIMS were left unchanged.

Discussion of Final Product Results

From Table 9, it again appears that Test 8 is the better of the tests as regards Mn with a value of 1.23 which is approaching the target of <1%. Test 4 has a higher Fe value (64.23%) as compared to 64.10%, but again the Mn is unacceptably high at 4.29%. Since the WHIMS on Test 4 were done on -150 M feed and on Test 8 at -325 M it would seem that finer grinding gives better Mn liberation. Again as expected, as the Mn content in the Fe concentrate decreases, the Fe content appears to increase.

During this study it was found (from the Technical University of Nova Scotia, also carrying out a project on Wabush ores) that although Mn is variable throughout the ore, the amount in solid solution can be as high as

20%. Considering the Mn value of 1.23% compared to the Mn value in the feed of 6.90%, this means that only 12.4% of the Mn was left in the Fe concentrate. Since the solid solution values are variable we can not draw a conclusion that the 1.23% Mn is all in solid solution but it would seem quite possible that a great deal of it may be. If this is the case it would appear that Wabush Scully will have to continue their practice of selective mining and/or blending with low Mn ores to achieve an Fe concentrate of <1% which is their immediate goal. Their only other alternative would be to leach out the Mn, a technique they have already decided would be too expensive.

FINAL CONCLUSIONS

From this investigation it can be seen that very high Fe recoveries with exceptionally low SiO_2 grades can be achieved by flotation. However, Wabush Scully tailings, being very high in Mn content, tend to reduce the Fe concentrate to a low grade of 59% Fe. Also, the Mn cannot be separated from the Fe during flotation, resulting in an unacceptably high Mn content in the Fe concentrate of approximately 7% Mn. A survey of the recent literature on flotation confirms the above conclusion, i.e., there has not been found to date a specific reagent or modifier which will selectively activate or depress one of the components to produce an effective separation.

Since the Company had already rejected leaching the Mn as being too expensive, it was decided to attempt to lower the Mn content and increase the Fe in the Fe concentrate by a combination of low and high intensity magnetic separation.

Three of the Fe concentrates from flotation were blended together as feed for the magnetic separations. The average assays of this feed were Fe - 59%, Mn - 7.11% and SiO_2 - 0.96%.

The results from Wet Low Intensity Magnetic Separation yielded 5.9 wt. % magnetite assaying Fe - 69.38%, Mn - 1.10% and SiO_2 - 0.46%, and 94.1 wt. % hematite assaying Fe - 58.29%, Mn - 7.32% and SiO_2 - 1.03%. Fifty-gram samples of the hematite feed composed of two different size distributions (-150 M and -325 M) were subjected to Wet High Intensity Magnetic Separation at varying conditions within the separator. The results obtained from these

samples were recombined with the magnetite from Wet Low Intensity Magnetic Separation and the best final product determined.

This product assayed 64.1% Fe, 1.23% Mn and 0.69% SiO_2. Although the Fe and Mn fall outside the desired values of 65% and <1.0% respectively, the SiO_2 is substantially lower than the <2.0% which was required.

It is felt that the Fe grade of 65% could be readily achieved but because of Mn in solid solution it would appear quite unlikely that a Mn value of <1% can be obtained.

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